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Description

Method and apparatus of determining properties of a signal transmission channel

The invention relates to a method of determining properties of a signal transmission channel between a first subscriber end point and a second subscriber end point of a telephone network having a plurality of subscribers, wherein a first subscriber terminal is connected to said first subscriber end point and a second subscriber terminal is connected to said second subscriber end point, wherein said telephone network upon request of a subscriber establishes a signal transmission channel between said first subscriber and said second subscriber, wherein said first subscriber end point is connected to the telephone network by a digital channel portion. The invention further relates to a subscriber terminal in a telephone network having a plurality of subscribers, wherein said telephone network upon request of a subscriber establishes a signal transmission channel between selected subscribers, said subscriber terminal being connected to a subscriber end point of said telephone network.

Recently, substantial progress has been made in increasing the data transmission rates when transmitting data over conventional analogue telephone lines. The International Telecommunications Union (ITU) has promulgated and published various recommendations, such as V.32, V.32bis, or V.34, that are concerned with data transmission over telephone lines. These recommendations are all based on a transmission technique called quadrature amplitude modulation (QAM). QAM has proven advantageous for the plain old telephone system (POTS) environment.

Nevertheless, the network of telephone system has undergone massive changes in that the network is nowadays almost

entirely digital. The analogue signals originating from a
first subscriber modem are converted at the subscriber's
central office to digital representations which are carried
through the digital telephone network. At the central office
5 of a second subscriber, the digital signals are converted
back into analogue signals to be driven into a second
subscriber's subscriber line. The second subscriber's modem
interprets the analogue signals on the analogue subscriber
line by demodulating the QAM signals produced by the first
10 subscriber's modem. The same way of data communication is
carried out in the reverse direction.

Increasingly more subscribers are connected to the telephone
network through a digital subscriber interface, such as ISDN.
15 Thus, many data connections are established between a first
subscriber having an analogue network interface and a second
subscriber having a digital network interface. In many cases,
the second subscriber will be an internet service provider.
In order to optimise data transmission over such
20 heterogeneous communication channels, various proposals have
been made in the recent past. One such proposal is known from
US 5,801,695.

The proposal is based on the idea that the transmission rate
25 in a heterogeneous communication channel from the digital
subscriber to the analogue subscriber may be raised by using
a PCM coding technique instead of the former QAM modulation
techniques. The PCM coding technique uses a plurality of
signal levels for encoding data symbols (each data symbol
30 comprising multiple bits). These signal levels are again
recognised by the receiving modem which is then able to
decode the data symbol encoded into the signal levels.

Further, ITU has promulgated a new recommendation V.90 in
35 September 1998. The new recommendation also relies on a PCM
coding technique for the transmission of data from the
digital subscriber to the analogue subscriber. Draft

recommendation V.90 in terms of its PCM coding scheme depends on ITU-T recommendation G.711 describing Pulse Code Modulation (PCM) of Voice Frequencies which is generally applied in telephone networks throughout the world when
5   converting analogue signal amplitude values into numeric representations thereof, and vice versa. G.711 recommends two PCM coding schemes generally known as μ-law, which is applied in North American telephone networks, and A-law, which is applied in most other telephone networks. Both coding schemes
10   have in common that they have a logarithmic coding characteristic, i.e. the lower the signal amplitude value to be encoded, the more fine-grain the available PCM codes. Such logarithmic coding characteristic has been found to be particularly advantageous for encoding analogue voice signals
15   at minimum distortion.

Recommendation G.711 makes available 256 PCM codes (or U-codes as called in V.90) which are grouped into eight positive and eight negative segments (or U-chords as called
20   in V.90). Each PCM code is encoded using eight bits. Due to power restrictions on the analogue telephone line and due to line impairments, the analogue modem (according to the terminology used in the draft to V.90) receiving analogue amplitude values is unable to discriminate between all 256
25   available PCM codes. Therefore, a reduced set of PCM codes is determined for encoding data symbols during set-up of a data communication channel under real world conditions. This accordingly lowers the data transmission rate down from the maximum theoretical possible value of 64 kbit/s such that it
30   is not above 56 kbit/s.

ITU-T Recommendation V.90 assumes an environment where one subscriber terminal of a connection is connected to the telephone network through a digital line and the other
35   subscriber terminal of the connection is connected to the telephone network through an analogue line. However, in many instances, both subscriber terminals of a connection are

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connected to the telephone network through a digital
connection. This situation would allow to establish an all-
digital channel between the two subscriber terminals at a
data rate of 64 kbit/s, which is the standard data rate in
5   telephone networks.

US 5,151,398 discloses modem line probing signal techniques.
These probing techniques relate to former analogue line
modems defined for example in ITU-T V.34.
10

It is an object of the invention to provide a line probing
scheme in order to detect an all-digital connection path
between subscriber terminals of a telephone network.

15   This object is achieved by a method having the features of
claim 1 or claim 4. The object is further achieved by an
apparatus having the features of claim 11 or claim 12.
Advantageous embodiments thereof are set out in the
respective dependent claims.
20

A first embodiment of the invention pertains to a method of
determining properties of a signal transmission channel
between a first subscriber end point and a second subscriber
end point of a telephone network having a plurality of
25   subscribers. A first subscriber terminal is connected to said
first subscriber end point and a second subscriber terminal
is connected to said second subscriber end point. Said
telephone network upon request of a subscriber establishes a
signal transmission channel between said first subscriber and
30   said second subscriber. Said first subscriber end point is
connected to the telephone network by a digital channel
portion. In a first step, said first subscriber terminal
sends to said second subscriber terminal a digital probing
signal comprising a sequence of frames, each frame comprising
35   a sequence of digital symbols, each symbol having a plurality
of bits. The digital values of all symbols over all frames
are equal except for one bit position of each symbol, the

value of which changes with every other frame. Said second
subscriber terminal then receives a signal which is the
result of said digital probing signal having been transmitted
through said signal transmission channel. Said second
5   subscriber terminal evaluates said received signal by
comparing said received signal with said digital probing
signal. Eventually, said second subscriber terminal
transmitting a response signal to said first subscriber
terminal, said response signal carrying information about the
10   comparison result.

A second embodiment of the invention also concerns a method
of determining properties of a signal transmission channel
between a first subscriber end point and a second subscriber
15   end point of a telephone network having a plurality of
subscribers. This method alternatively provides that said
first subscriber terminal sends to said second subscriber
terminal a digital probing signal comprising a sequence of
frames, each frame comprising a sequence of digital symbols,
20   each symbol having a plurality of bits, wherein the digital
values of all symbols are equal except for at least one pulse
symbol of each frame having a significantly different digital
value compared to the remaining equal values.

25   The line probing schemes proposed by the invention allow both
to find out whether an all-digital transmission channel is
present between said first subscriber end point and said
second subscriber end point and further to find out the
transmission properties of the all-digital transmission
30   channel. Since the transmission channels of most telephone
networks are primarily intended for voice signal
transmission, some networks impose digital signal impairments
upon the digital signals carried through the network's
channels. Such digital impairments include digital padding
35   (digital signal attenuation), robbed bit signalling, ADPCM
(Advanced Differential Pulse Code Modulation) coding and
voice compression algorithms. The latter impairments allow to

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reduce the bit rate of 64 kbit/s generally reserved for a
full channel to a lower rate without much sacrifice to the
quality of voice signal transmission, thus making available
bandwidth for other purposes. The methods of the invention
5   are capable of discriminating whether an all-digital channel
is present and whether or not the all-digital channel has
digital impairments. The methods of the invention are even
capable of discriminating what kind of digital impairment is
present in an all-digital transmission channel. Knowing the
10   kind of digital impairment allows the conclusion as to
whether a transmission scheme between said first subscriber
terminal and said second subscriber terminal is possible
according to V.90 or another lower rate scheme such as V.34.

15   In the first embodiment, it is preferred that said one bit
position is the most significant bit position. This way, the
absolute digital value difference from one frame to another
is as large as possible. It is even further preferred that
said one bit position is the position of the sign bit. This
20   way of line probing ensures that no direct current is
produced in an analogue channel portion which may be present
in the transmission channel to be probed.

In the second embodiment, it is preferred that one bit
25   position of said at least one pulse symbol changes value with
every other frame. Thus, frames can be identified as such
more easily by the second subscriber terminal. In an even
more preferred embodiment, said one bit position is the
position of the sign bit. This ensures that no direct current
30   is produced in an analogue channel portion which may be
present in the transmission channel to be probed.

In the second embodiment, it is preferred that the number of
equal symbols per frame is significantly higher than the
35   number of pulse symbols. This allows said second subscriber
terminal to clearly identify a pulse symbol as such.
Preferably, there is one pulse symbol per frame.

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Alternatively, there may be two pulse symbols per frame. It
is most preferred that the total number of symbols per frame
is 80.

5   Further advantages, features and areas of using the invention
are explained in the following description of a preferred
embodiment of the invention which is to be read in
conjunction with the attached drawings. In the drawings:

10 Fig. 1a   shows the configuration of an all-digital signal
            transmission path in the presence of digital
            impairment;

    Fig. 1b   shows the configuration of a signal transmission
15   path having an analogue portion;

    Fig. 2   is a signal diagram of a probing signal and a
            received signal according to a first embodiment of
            the invention;

20 Fig. 3   depicts a digital symbol sequence of a probing
            signal and various received signals according to a
            second embodiment of the invention.

25 Fig. 1a illustrates an all-digital signal transmission path
    between a first subscriber terminal 1 and a second subscriber
    terminal 8. The first subscriber terminal 1 (a digital modem)
    is connected through a digital line portion 2 to a local
    digital switch 3. The local switch 3 is connected to a
30 digital transmission network 4 which forwards digital signals
    between subscribers of the transmission network. On the other
    end of the all-digital signal path, the second subscriber
    terminal 8 is connected through a digital line portion 7 to a
    local digital switch 6. The local switch 6 is connected to
35 the transmission network 4 through a digital impairment
    device 5. Fig. 1a shows an exemplary position of the digital
    impairment device within the transmission path. The digital

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impairment device may as well be part of any of the digital
switches 3 and 6 or may be part of the transmission network 4
or of the transmission path 7.

5   Digital impairments include digital padding (digital signal
    attenuation), robbed bit signalling (RBS), and ADPCM
    (Advanced Differential Pulse Code Modulation) coding or other
    voice compression algorithms which may be imposed upon the
    signals passing through the impairment device 5. Digital
10 impairment devices are present in many existing transmission
    networks and have to be accounted for when trying to
    establish a connection between subscriber terminals of the
    network at the highest bit rate possible.

15 Fig. 1b shows a similar configuration as Fig. 1a except that
    the second subscriber terminal 8' is connected to the
    transmission network through an analogue line portion 7'. The
    transmission path of Fig. 1a consequently includes a hybrid
    device 9' which is connected to the analogue line portion 7'
20 and performs a four-wire to two-wire conversion.
    Additionally, the hybrid device 9' performs, on the four-wire
    side, a digital-to-analogue and an analogue-to-digital signal
    conversion so as to be connected to a digital switch 6'. The
    remaining structure of Fig. 1b corresponds to the one shown
25 in Fig. 1a. Thus, the description of the remaining elements
    may be referred to by similar reference numerals.

    Both Fig. 1a and Fig. 1b illustrate exemplary structures of
    transmission paths that may be encountered when trying to
    establish a connection between two subscribers of a
    transmission network wherein at least of the two subscribers
    is connected to the network through a digital line portion
    such as ISDN. Depending on the structure encountered on the
    transmission path between the subscribers, they may agree
35 upon a certain transmission scheme allowing a bit rate as
    high as possible for the encountered structure. Known
    transmission schemes are ITU-T V.34 using quadrature

amplitude modulation on analogue transmission paths and ITU-T
V.90 using pulse amplitude modulation on transmission paths
having both analogue and digital line portions. Further,
pulse amplitude modulation according to ITU-T V.90 can also
5   be used as a transmission scheme on all-digital transmission
paths.

Fig. 2 is a diagram of a probing signal of the first
embodiment of the invention. The probing signal is
10   transmitted by the first subscriber terminal 1 and of a
signal received by the second subscriber terminal 8 in the
presence of a digital impairment device 5 introducing ADPCM
to the signal transmission path between the first subscriber
and the second subscriber. Terminal 1 sends 80 digital
15   symbols of equal value in a first frame and then sends 80
digital symbols of the same absolute value, however, being
negative in sign. The probing signal consists of a plurality
of frame pairs as illustrated in Fig. 2 subsequently
transmitted by the first terminal 1.

20
In the presence of ADPCM in the transmission path, the
received signal does not precisely follow the large signal
swings from one frame to another. The second terminal 8 may
interpret this as an all-digital transmission path which is
25   not transparent due to ADPCM. Such a connection is not
capable of carrying an ITU-T V.90 transmission scheme.

Fig. 3 shows a digital symbol sequence of a probing signal
(sequence a) transmitted by the first subscriber terminal 1
30   (Modem 1) according to a second embodiment of the invention
and various cases of received signals (sequences b through
g). Fig. 3 shows a frame structure of 9 symbols per frame. It
is preferred to use a much higher symbol count per frame,
preferably 80 symbols per frame. Each digital symbol shown in
35   Fig 3 is a hexadecimal representation of an 8 bit digital
value corresponding to the U-code representation as defined
in ITU-T V.90. The first symbol of the first probing frame in

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sequence (a) is 4Ch (the character h indicating hexadecimal
representation in this text). The first symbol of the second
probing frame in sequence (a) is CCh, which is equal to 4Ch
except for one bit position. According to ITU-T G.711, this
5   bit position is the sign bit of a signal represented by the
digital symbol. All remaining symbols are at value 00h. Thus,
the first symbol forms a signal pulse.

Sequence (b) of Fig. 3 shows the signal received by
10 subscriber terminal 8 (Modem 2) in the case of an all-
digital, fully transparent connection. Thus the frame sent by
modem 1 is received by modem 2 with identical symbols, merely
displaced in time. This case allows to establish a PCM
transmission scheme between modem 1 and modem 2. Sequence (b)
15 through (g) show received signals in the presence of digital
impairments. Sequence (c) assumes an impairment of digital
padding, i.e. the digital signal is attenuated. Thus the
pulse symbol in the original probing sequence (a) is lower in
its absolute value.
20

Sequence (d) shows a received signal in the presence of
digital impairment in the form of robbed bit signalling
(RBS). RBS is applied to a least significant bit of every
sixth symbol. Thus, the received signal differs from the
25 original probing sequence every sixth symbol. Sequence (e)
shows a received signal in the presence of both digital
padding and RBS. Thus, the effects of both impairments appear
as a superimposed effect on the received signal.

30 Finally, sequence (f) shows a received signal under the
influence of ADPCM or another voice compression algorithm.
The ADPCM coder cannot follow the high pulse symbol 4Ch of
the probing sequence interspersed in the zero symbols 00h.
Thus, the pulse symbol of modem 1 is received with a much
35 wider pulse width and less high amplitude in modem 2. This is
a clear indication of ADPCM.

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The invention generally also relates to a modem connected via
a digital interface to a switched public telephone network.
The modem communicates with a second modem also connected via
a digital interface to the same switched public telephone

5   network. Thus, there may exist the possibility to set up a
connection between both modems with a transmission rate of 64
kbit/s on the basis of coding voice signals with pulse code
modulation according to ITU-T recommendation G.711. The
public telephone network may incorporate voice compression

10   devices (ADPCM G.726, G.723 etc.), digital pads (digital
attenuators), robbed bit signalling and echo cancelling
devices.

Under such circumstances, digital encoding schemes like pulse

15   amplitude modulation according to ITU-T V. 90 instead of
known analogue schemes like ITU-T V.34 may be utilised to
transfer data. In order to apply such a digital coding
scheme, it needs to be assured that an all-digital channel
has been established between the modems. Assuring this may be

20   carried out by an appropriate probing signal sent through the
transmission channel. Known probing techniques have proven
that they cannot discriminate all possible channel
configurations.

25   The probing sequence of the invention uses large amplitude
changes in a symbol sequence (each symbol having a duration
of 125 µs). The meaning of amplitude relates to the
definition of ITU-T recommendation G.711. After that single
amplitude change, the signal may return to the previous value

30   or continue with the new amplitude value for a number of
symbols. The number of symbols is selected to be larger than
any expected impulse response of a digital impairment of the
channel. The amplitude value change must be large enough to
produce a sufficient result in the presence of digital pads

35   with or without the presence of RBS.

The receiving modem will evaluate the received symbols and search for amplitude changes. If these changes occur only for one symbol per frame and the following symbols either return to the previous value or remain at the new value, the connection is detected as capable to carry a V.90 transmission scheme. If, however, the symbols after an amplitude change do not remain at the new value or do not return to the value before the change (in other words there is an impulse response over time), it is determined, that a connection according to ITU-T V.90 is not possible. Typical impairments having an impulse response are voice compression algorithms and ADPCM, which may be regarded a compression algorithm, too. Whereas ADPCM has a characteristic impulse response to an change in amplitude, it depends on the design of a voice compression algorithm how large amplitude swings are processed and coded into the output signal of the voice compression coder.

Robbed bit signalling changes the least significant bit (LSB) in some symbols but leaves the remaining seven bits unchanged. A single amplitude change will therefore only be affected in the LSB, the remaining seven bits, however, will not change. Digital pads use conversion functions which defines an output value to a PCM input value thus providing digital attenuation. This function will only change the absolut value of the amplitude but it will not affect the behaviour of the signal over time.

In an implementation, modem 1 will generate a pattern as described in conjunction with Fig. 3 and sends the pattern through the transmission channel to modem 2. Modem 2 will receive a pattern which differs from the transmit pattern due to network impairments. Modem 2 will evaluate the pattern in the following way: It will first logical AND the pattern with FEh in order to ignore changes in the LSB. Next it will compare this new value with the previous one. If they are identical, a counter is incremented. If they are different,

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then the current count value is compared to the expected value and if they differ, an error counter is incremented. Then the counter is reset to zero and the new value is transferred to the old value register. When all symbols have been evaluated, the value of the error counter is compared to a fixed threshold value. If the error counter value is below the threshold, then it is determined that the connection is not capable of carrying an ITU-T V.90 type transmission scheme.

The appended program codes show how line probing signals according to the invention may be produced. The programs are based on a pseudo code. The program of appendix A corresponds to the embodiment of Fig. 2, and the program of appendix B corresponds to the embodiment of Fig. 3. By no means are these program a limitation of the invention.

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Appendix A

Example of program code for alternating pattern:

Transmit_Pattern:

```
Loop_COUNT = 20
High_Code = 4CH
Low_Code = CCH
Total_count = 100

For (i;I=0;I=Total_count)
      {
      For (j;J=1; j=Loop_Count)
            SendPCMvalue (Low_code);

      For (j;J=1;j=Loop_Count)
            SendPCMvalue(High_Code);
      }
```

Receiver:
```
Loop_Count = 20
Total_count = 100 * 2 * Loop_Count

Old = 0;
Error = 0;
Count = 0;

For (i;i=0;i=Total_count)
      {
      a = (GetnewPCMvalue() && 11111110B)          ;Masked LSB
for REF impact
      If (Old <> a)
            count++
      ELSE
```

15

```
        IF (COUNT <> LOOP_COUNT-1)
                Error++
            count = 0
        Old = a;
        )

    If (Error > 1)
        Return (False)
    Return (True)


)
```

Appendix B

Example code for single value pattern detection:

Transmit_Pattern:


```
Loop_COUNT = 20
High_Code = 4CH
Low_Code = 00H
Total_count = 100



For (i;I=0;I=Total_count)
     {
     For (j;J=1; j=Loop_Count-1)
          SendPCMvalue (Low_code);

     SendPCMvalue(High_Code);

     For (j;J=1; j=Loop_Count-1)
          SendPCMvalue (Low_code);

     SendPCMvalue(High_Code EXOR 80H);

     }


Receiver:
Loop_Ccunt = 20
Total_count = 100 * (LoopCount)

Old = 0;
Error = 0;
Count = 0;

For (i;i=0;i=Total_count)
     {
```

```
        a = (GetnewPCMvalue() && 11111110B)        ;Masked LSB
    for RBS impact
        If (Old <> a)
            count++
5       ELSE
        {
            IF (COUNT <> LOOP_COUNT-2)
                IF (COUNT <> 0)
                    Error++
10          count = 0
        Old = a;
        }

   If (Error > 1)
15     Return (False)
   Return (True)
```